SEARCH FOR DARK MATTER USING MONO-HIGGS EVENTS IN THE FOUR LEPTON FINAL STATE AT CMS

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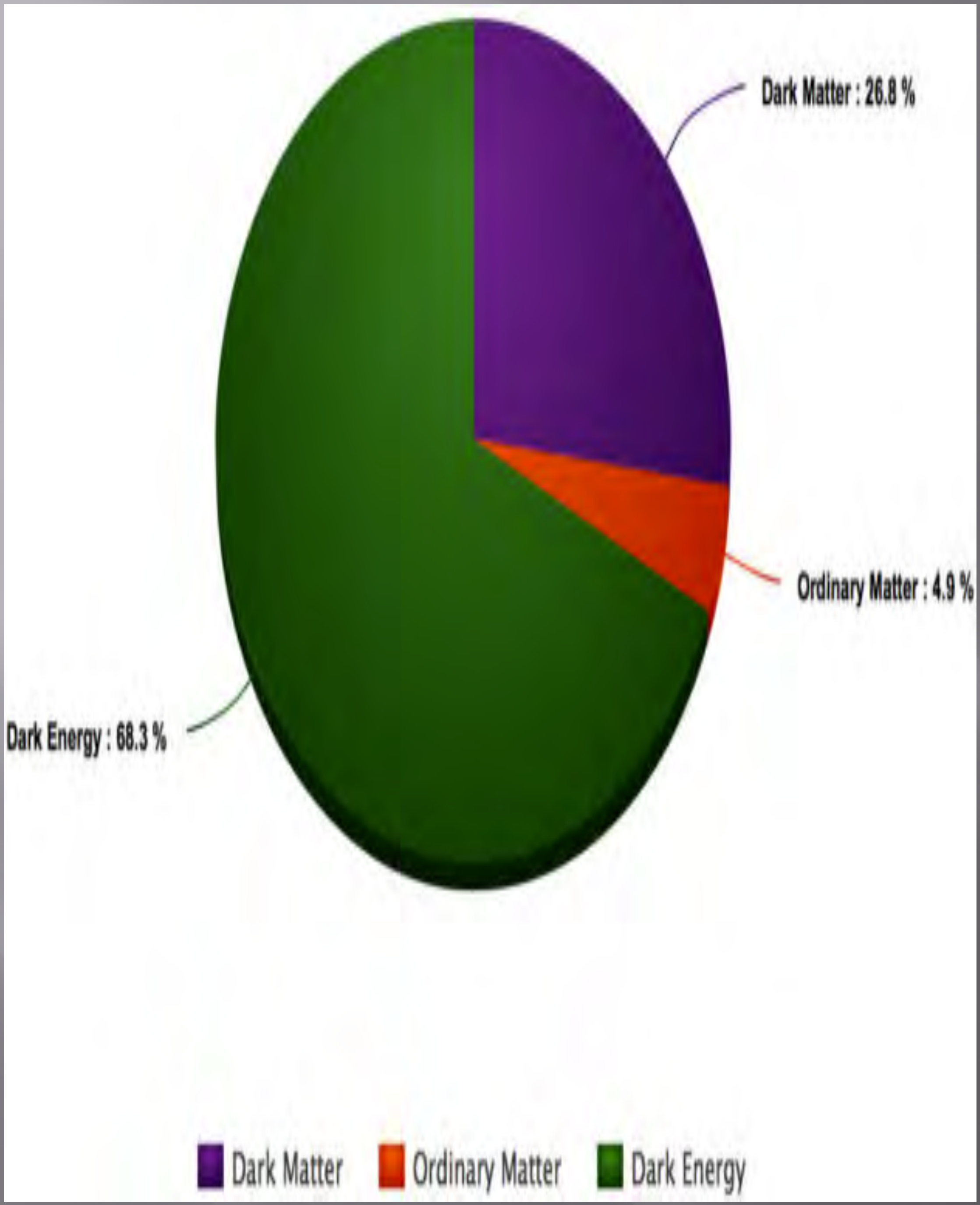


- Dark matter seems to outweigh visible matter, making up about 27% of the universe.
- We can only detect dark matter from its gravitational effects.
- If such particles interact non-gravitationally with standard model particles detecting it through high-energy collisions at particle accelerators is one of the most promising avenues towards identifying the specific nature of its detailed interactions.

*Photo credit: http://newscenter.lbl.gov/2016/05/24/3-knowns-3-unknowns-dark-matter/

- Dark matter particles could be produced at the Large Hadron Collider, but would escape detection being stable and weakly interacting.
- The standard model Higgs boson can provide an additional probe beyond the Standard Model into the dark matter sector.
- Experimentally, these “mono-Higgs” events are characterized by the presence of a Higgs boson and non negligible missing transverse momentum due to the undetected dark matter particles.

- In order to plot and analyze the data, background, and signal distributions ROOT version 6.06/01 was used.
- ROOT is an object-oriented program and library developed by CERN. It is mainly written in C++ but integrated with other languages such as Python and R.

ROOT
Data Analysis Framework

*photo credit: root.cern.ch

- TNtuples with various calculated variables were provided to work with.
- A TNutple is a TTree restricted to a list of float variables.
- A TTree consists of a list of independent branches, and each branch has its own definition and list of buffers.

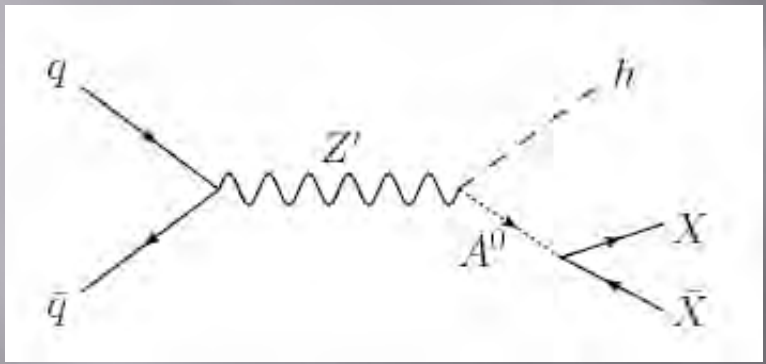
- The study focused on the decay of the standard model-like Higgs boson to two Z bosons both decaying to charged leptons. ($H \rightarrow ZZ \rightarrow 4l$)
- The TNtuples were separated into the three different decay channels of the leptons.
  - Two electrons two muons (2e2mu)
  - Four electrons (4e)
  - Four muons (4mu)
- 2015 data was collected from CMS for this study had a luminosity of 2.8 fb^{-1}

Background processes

- gg→ttH→ttZZ→4l+X
- tt→2l2v2b
- qq →Hqq →ZZqq →4lqq
- WJets →lv
- qq →W^-H →W^-ZZ →4l+X
- qq →W^+H →W^+ZZ →4l+X
- WW →2l2v
- WZ →3lv
- qq →ZH →ZZZ →4l+X
- Z →ll, H →2lvv, l=e, μ
- qq →ZZ →4l
- Z →ll+jets
- gg →H →ZZ →2e2mu
- gg →H →ZZ →2e2tau
- gg →H →ZZ →2mu2tau
- gg →H →ZZ →4e
- gg →H →ZZ →4mu
- gg →H →ZZ →4tau

Signal:
Two Higgs Doublet Model (2HDM)

SIMPLIFIED MODEL

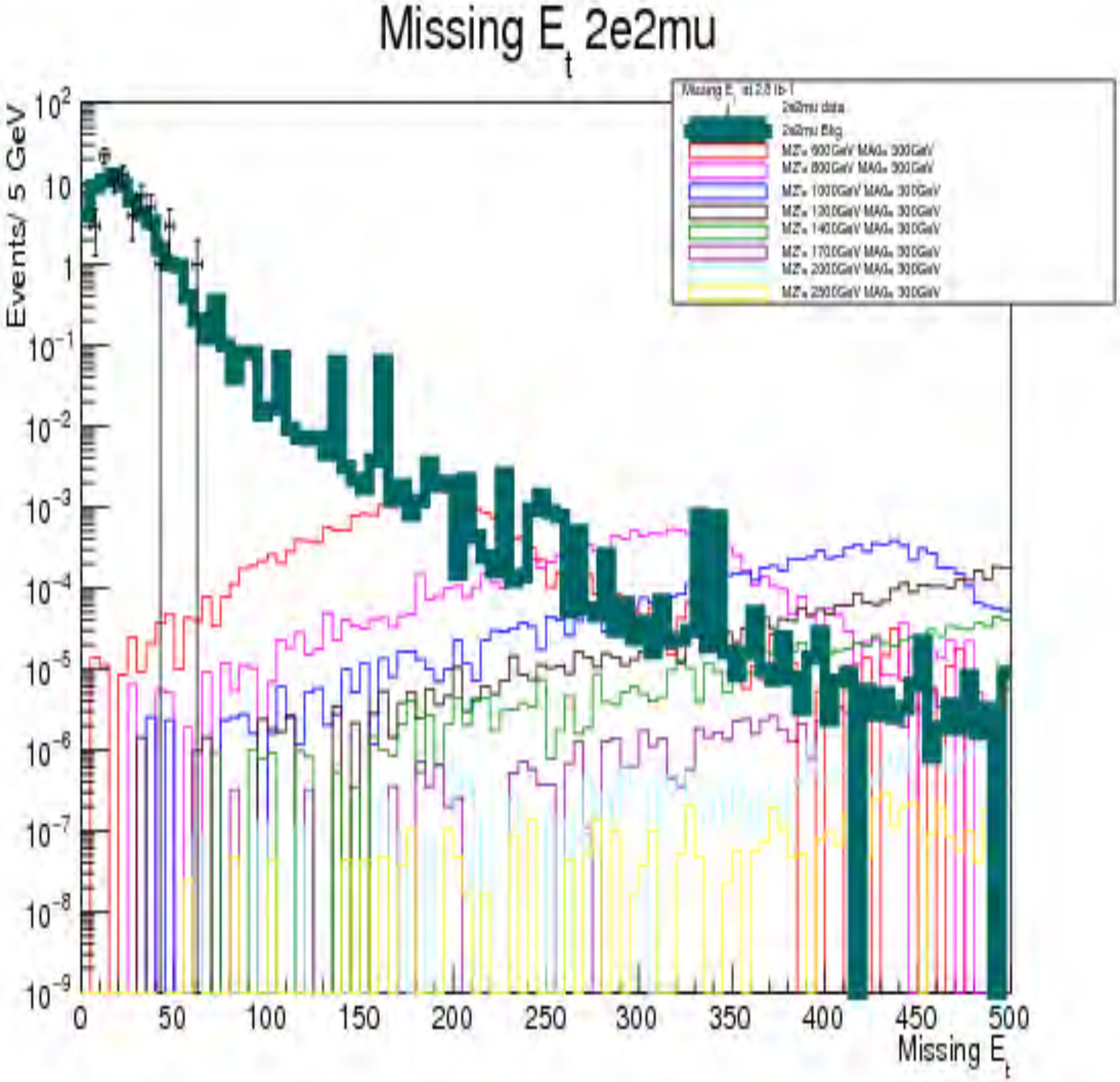


Z' DECAYS TO A HIGGS PLUS AN INTERMEDIATE STATE WHICH DECAYS TO A DARK MATTER PAIR.

- A standard model state decaying to dark matter is highly constrained.
- However dark matter-standard model particle interactions mediated by a pseudoscalar particle (Z') are possible, evading constraints from direct detection experiments.

- The models used in my study differed in the mass of the Z' with A^0 set to 300GeV.
- Z' = 600GeV, 800GeV, 1000GeV, 1200GeV, 1400GeV, 1700GeV, 2000GeV, 2500GeV

RESULTS



Backgrounds and signal models are weighted to 2.8 fb^{-1}

Number of events(data) per channel

2e2mu=70

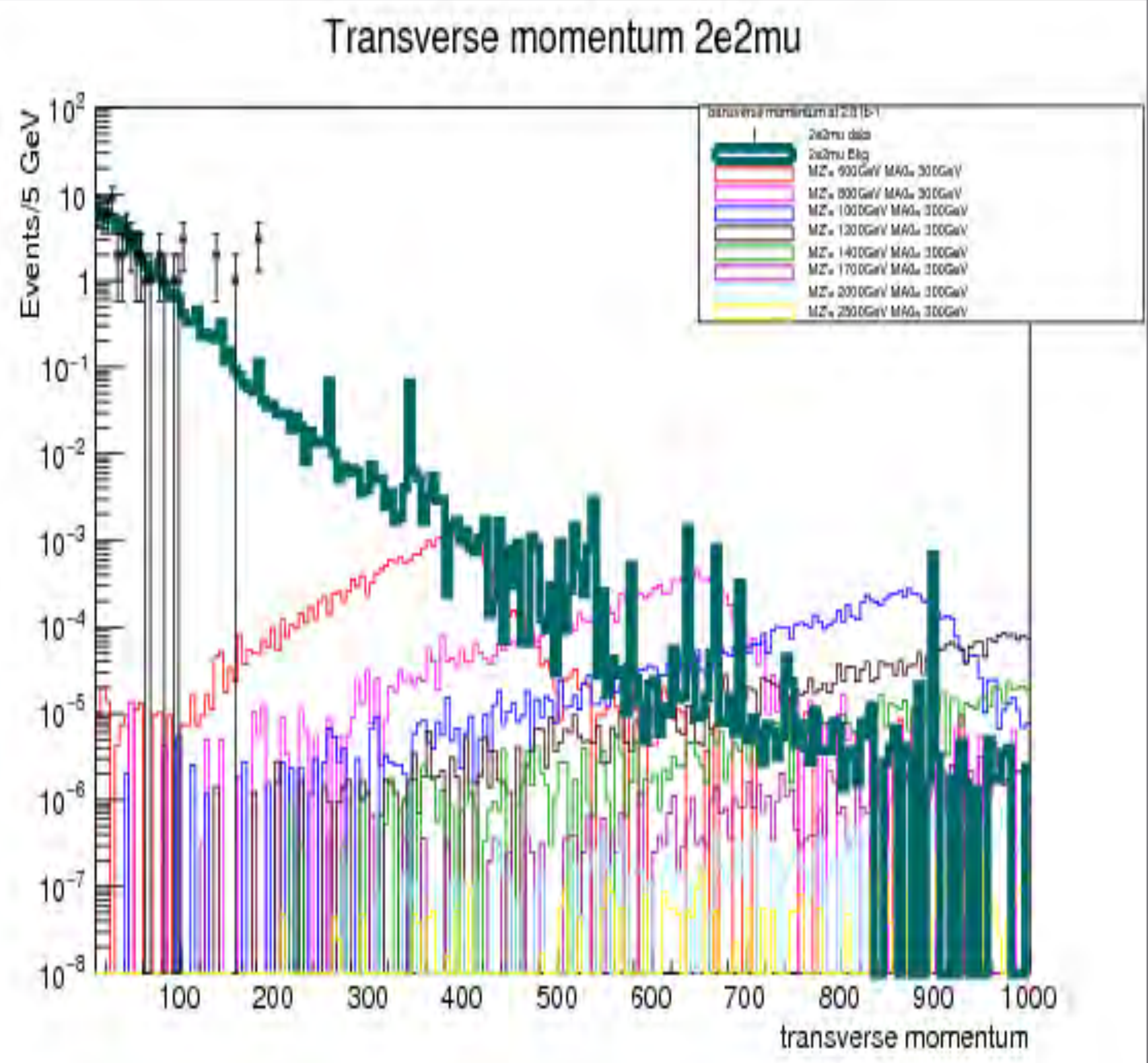
4e=20

4mu=49

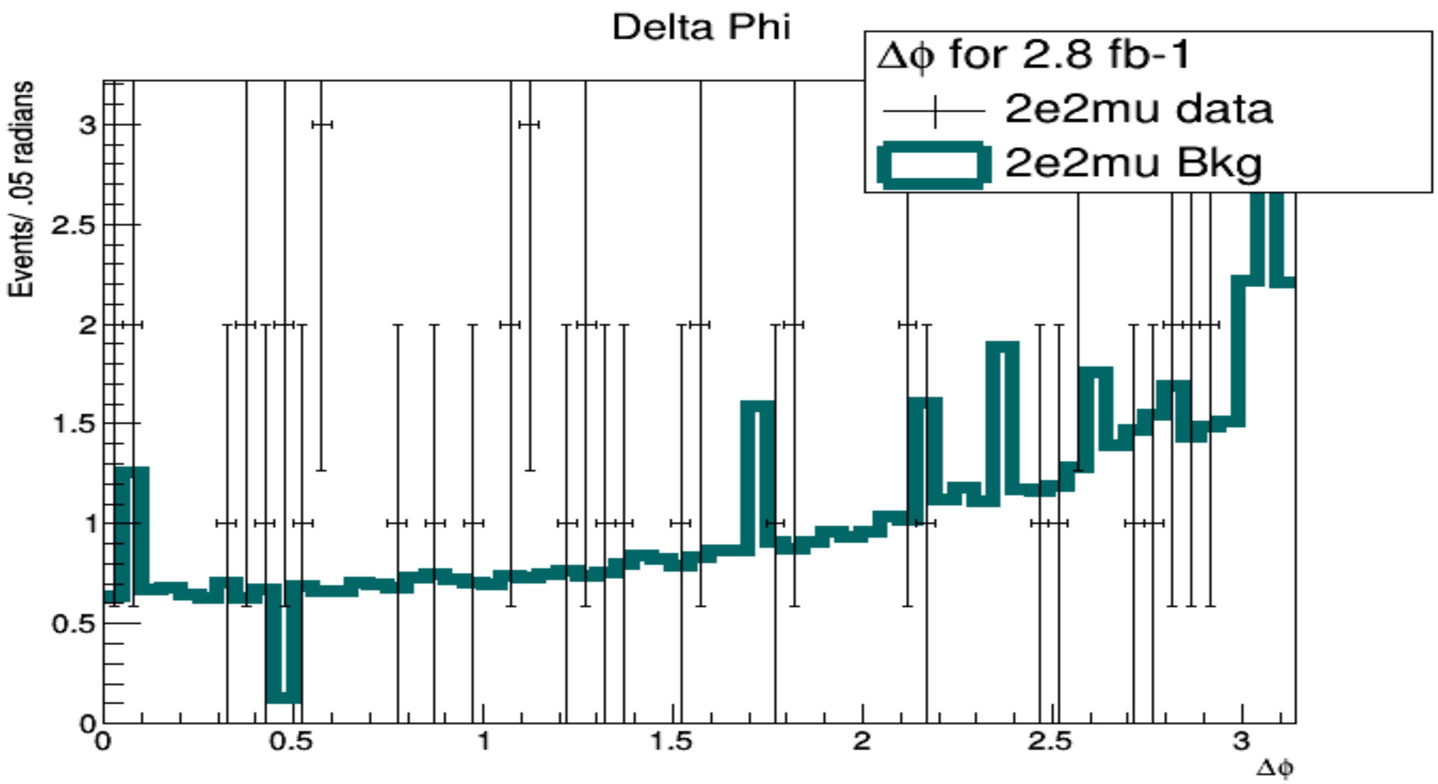
The Missing E_T of the data is negligible and explained by the Standard Model

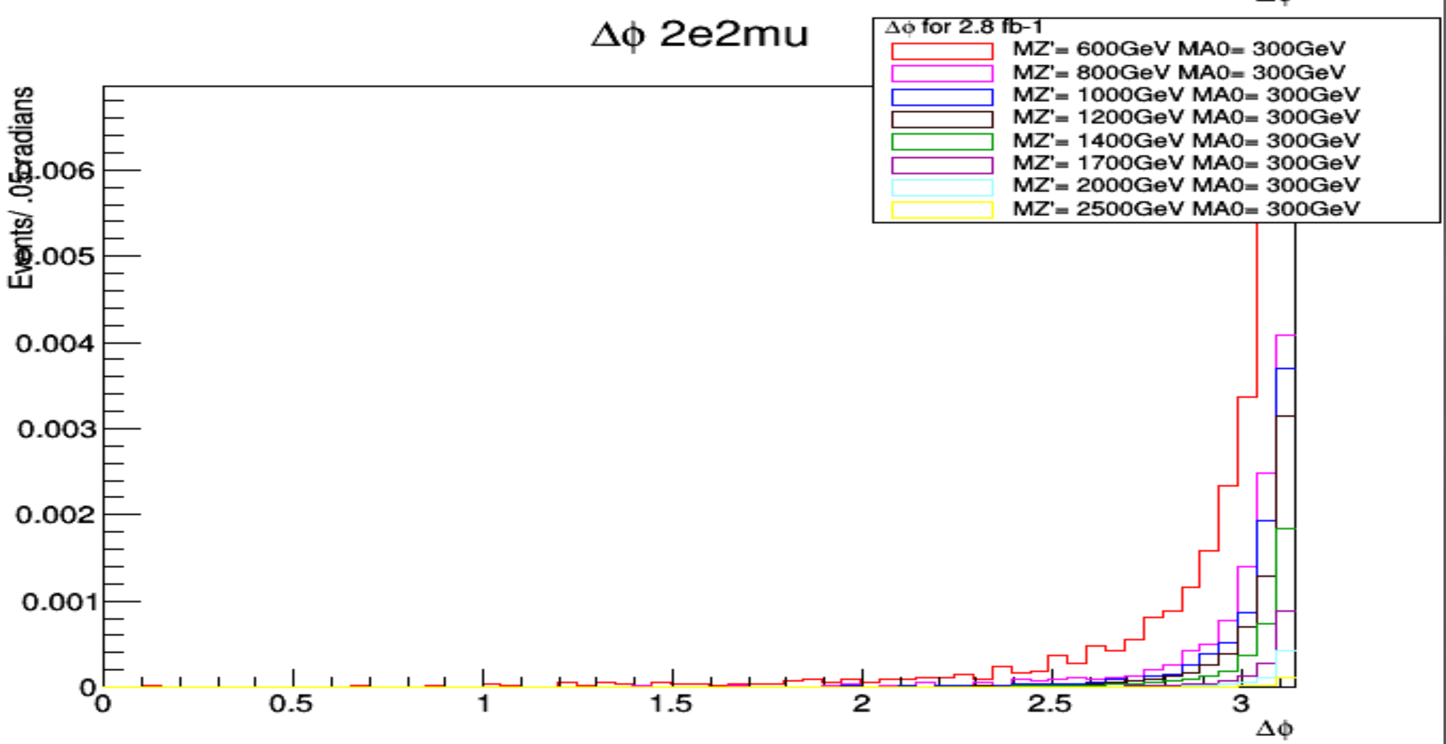
Missing E_T events at 2.8 fb^{-1}

	Signal			
	MZ’=600GeV	MZ’=800GeV	MZ’=1000GeV	Background
$ME_T > 150$	0.02148	0.01108	0.008606	0.40146
$ME_T > 250$	0.00171	0.00909	0.008158	0.06187



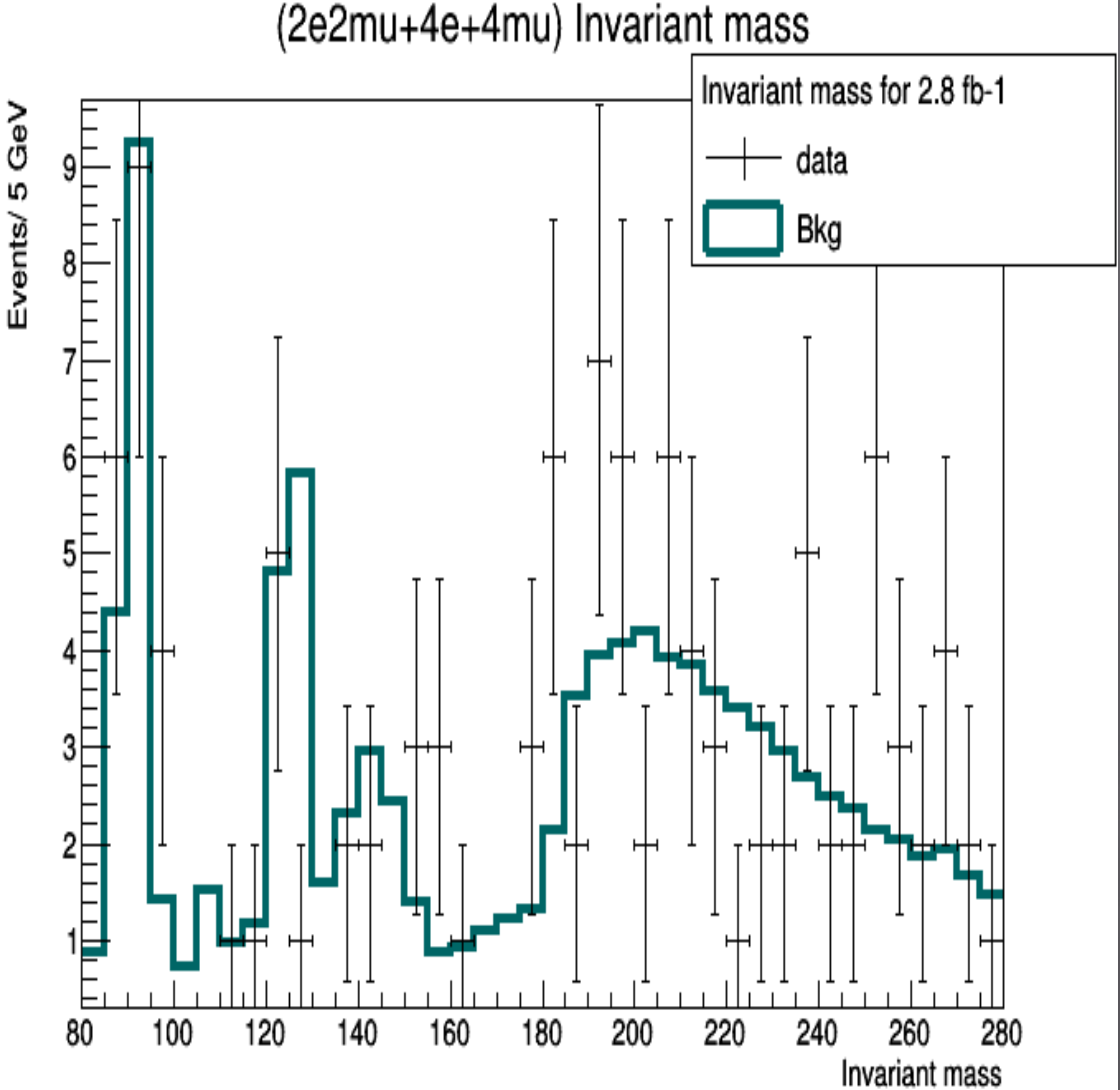
Events (data) do not extend into the range modeled by the signal models





There is a significant amount of the signal after $\Delta\varphi > 2$ radians while the background has an even distribution

Making a cut at $\Delta\varphi > 2$ radians will allow for significant amount of background rejection while at the same time allowing for a significant amount of the signal to remain



Invariant mass of the four leptons

The peak at 125GeV suggest Higgs production

Conclusion

- There is no significant missing E_T in the 2015 data
- The data is well modeled by the standard model background
- We need a lot more data to have significant sensitivity in this channel
- Advanced Multivariate Analysis should improve signal/background separation and sensitivity

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- My fellow SIST interns
- And my carpool

Questions?

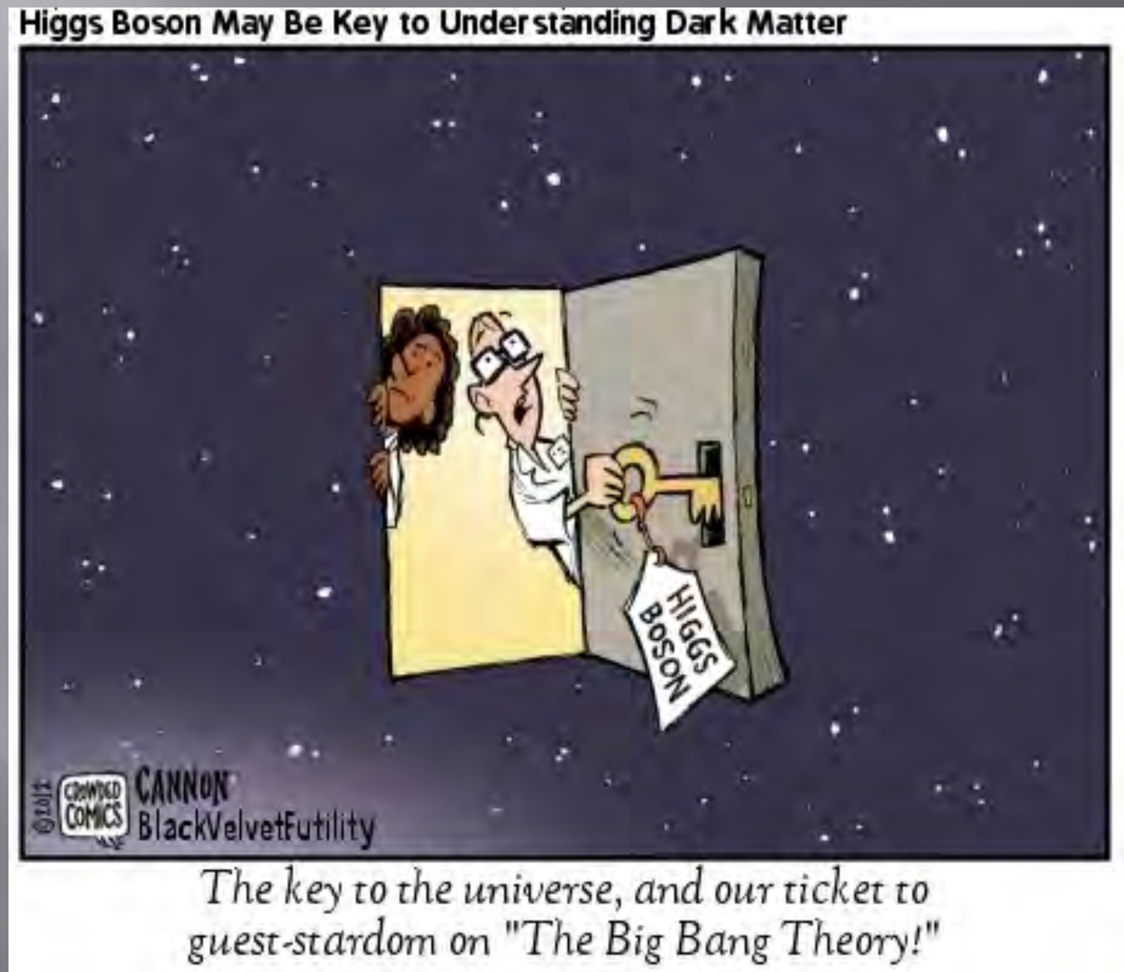

*photo credit: www.crowdedcomics.com